environmental damage. Further, time taken to recapture biofuel emissions and the energy source's opportunity cost on land are likely to limit its use to specific functions such as jet fuel.

National Renewable Energy Laboratory data reveal that major economies, such as Russia, the United States, China, Brazil, Canada and Australia are well endowed with wind and solar energy potential (National Renewable Energy Laboratory, 2020a, 2020b). On a per capita basis, Australia and Canada are particularly well placed; a position which is strengthened by access to developed capital markets, strong institutions and an educated workforce. This suggests that it will be easier for some nations to achieve net zero emissions.

Unlike fossil fuels, which have high energy density, renewable sources of energy are expensive to transport over very long distances. The two primary options: high voltage direct current and green hydrogen, either compressed hydrogen or liquified ammonia, remain poor substitutes relative to the economies achieved in the transportation of fossil fuels over equivalent distances.

According to Garnaut (2019), the cost of constructing and maintaining long distance high voltage transmission lines may cause transportation costs for energy to exceed the value of the energy itself. Examples include the AUD $20 billion Sun Cable project which proposes to build and link a 22-gigawatt solar farm in northern Australia to Singapore (Macdonald-Smith, 2020; Sun Cable, 2020). The project's proposed distance of 4500 kilometres is modest compared with the distances required to reach Asia's largest economies.

Green hydrogen, produced from the separation of water molecules using clean energy, has been widely touted as a means of exporting renewable power. Unfortunately, hydrogen's bulk and instability make it difficult, expensive and even somewhat dangerous to transport (Gerboni, 2016). Obtaining energy output equivalent to 70 litres of petrol (a full tank in a large car) requires 770 litres of hydrogen weighing approximately 530 kilograms (Koike, Miyagawa, Suzuoki, & Ogasawara, 2012).[4] Energy lost during liquification, about thirty per cent (Sørensen & Spazzafumo, 2018), and transport means that hydrogen could lose half its value between its point of manufacture and destination (Garnaut, 2019). Sørensen and Spazzafumo (2018) estimate that it costs about USD $3 per kilogram to transport hydrogen. To put this in perspective, coal is shipped at about USD $3 per tonne.

This suggests that transport costs matter in a low carbon global economy driven by renewable energy. Figure 1 illustrates changing relative transport costs through time where transport costs for physical goods were once high and a major determinant of industrial location yet have fallen to become negligible by the early 21st Century. In a low carbon economy dependent on renewable energy, transport costs are likely to increase again given the high cost of moving energy (a key input in production).

[4] This is reduced to 315L and 172kg, respectively, when using ammonia.

energy resources. This gives locations able to combine technical expertise, capital and surplus renewable energy resources a competitive advantage in key industrial sectors. Australia's favourable climate, developed capital markets, strong institutions, abundance of mineral resources and educated workforce make it a natural choice for an increased global share of energy intensive industrial activity.

It is expected that sectors which are more energy intensive will benefit most from relocation to regions with low-cost renewable energy. The speed with which this impacts industrial location is largely dependent on government policies and technological change. More stringent environmental regulations and higher carbon border taxes will likely accelerate movement to regions which can produce "green products", whilst reductions to renewable energy transport costs will diminish the importance of natural resource location.

The core thesis of this paper reinforces the importance of understanding comparative advantage as a fluid process (Cypher & Dietz, 1998). Technological change, as reflected in this paper, and government policies shape the strength and direction of a country's competitiveness. It is important to note that the advantage of surplus low-cost renewable energy generation potential must be combined with other factors for a nation to develop its industrial base. Greater adoption of renewable energy resources may also improve the spatial distribution of economic activity.[6] This is due to the high transport costs incurred in moving renewable energy and its abundance outside of urban areas (space intensive nature).

Carbon border taxes are likely to have a disruptive impact on supply chains and corporate profitability. Their imposition will drastically change operating costs and reduce the profitable life of production facilities with limited access to renewable energy resources. Companies which incorporate the dynamics discussed in this paper into their forward planning will be better placed to make effective capital budgeting decisions.

Overall, the influence of transport costs on industrial location is significant in a low carbon economy. Transport costs for renewable energy over long distances have re-emerged as a barrier to the centralisation of industrial activity away from natural resources. Whilst other factors remain in play, locational models will benefit from the inclusion of this dynamic. Future research may seek to better understand the trade-offs presented in this paper by quantitatively modelling the impact of renewable energy transport costs on the industrial location of energy intensive sectors under varying emissions reduction scenarios.

[6] A major challenge in developed economies (Glaeser & Gottlieb, 2009; Glasmeier, Martin, Tyler, & Dorling, 2008).

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